

manufacturing a large-diameter optical-fiber preform. FIG. 1 shows a conventional cooling apparatus employed in the process of drawing an optical fiber. As shown in FIG. 1, an optical fiber F1, which is drawn at a high temperature and a high speed, is cooled while passing through a cooling apparatus. Then, an optical fiber F2 having an appropriate temperature for coating is obtained. The cooling apparatus consists of a cooling body 30, and upper and lower irises 32 and 34, which are mounted on the upper and lower ends of the cooling body 30, respectively. Each of the irises 32 and 34 inhibits the ingress of external air and any minute movements of the optical fiber at the time of initial drawing.

The cooling body 30 has a double-walled structure of copper tubes and comprises a first copper pipe 310 and a second copper pipe 312, wherein the latter is coaxially located within the former. From each of the upper and lower ends of the cooling body 30, helium gas is supplied into the inner space 301 of the second copper pipe 320 in the directions indicated by the arrows 1, thus forming a helium-gas atmosphere in the inner space 301. As such, the drawn optical fiber passes through the inner space 301. Furthermore, a space for circulating the cooling water 302 of a low temperature is provided between the first copper pipe 310 and the second copper pipe 312 to cool the helium gas contained in the internal space 301 of the second copper pipe, so that the cooling water performs heat exchange with the drawn optical fiber F1 in a high temperature state. Through the heat exchange, the optical fiber F1 which is drawn at a high temperature is cooled to an appropriate temperature. In order to draw more optical fibers from a given optical-fiber preform, it is necessary to increase the efficiency of the process so that the optical fiber can be drawn at a speed higher than that of the prior art.

However, if an optical fiber is drawn from the preform at a high speed, external air may penetrate the internal space 301 of the second copper pipe through the upper iris 32. In other words, as the optical fiber is drawn at a high speed, airflow is generated in the region adjacent to the circumferential surface of the optical fiber, and due to the airflow
5 external air penetrates the internal space 301 of the second copper pipe, within which the helium atmosphere has been formed, thus reducing the density of helium within the internal space of the second copper pipe.

In particular, the helium density is reduced more in the region adjacent to the upper iris 32 within the cooling body 30. Such a reduction of helium density is the most
10 important cause of a drop in the cooling efficiency, and the operator must supply more helium gas than needed to the cooling apparatus in order to compensate the reduction of helium density. As a result, it is necessary for a manufacturer to supply more helium gas than needed to prevent a drop in efficiency which results from the reduction of helium density and causes an increase in costs.

15

SUMMARY OF THE INVENTION

Accordingly, the present invention has been made to solve the above-mentioned problems occurring in the prior art by providing a cooling apparatus that can enhance
20 cooling efficiency to allow high-speed drawing.

According to one aspect, the present invention provides a cooling apparatus that can reduce the amount of cooling gas needed.

According to another aspect, the present invention provides a cooling apparatus, which can increase turbulence in the molecular movements of cooling gas, thereby minimizing the consumed amount of cooling gas.

Accordingly, there is provided a cooling apparatus employed in the drawing
5 process of an optical fiber, comprising: a cooling body extending along the longitudinal
direction of the drawn optical fiber, wherein the cooling body consists of a left cooling
body part and a right cooling body part that are separable, and wherein the cooling body is
provided with a sealing cap so that cooling gas can be supplied into the cooling body
through the sealing cap; and, at least one turbulence generator that is mounted within the
10 cooling body to surround the drawn optical fiber, the turbulence generator activating
molecular movement of the cooling gas supplied into the cooling body.

BRIEF DESCRIPTION OF THE DRAWINGS

15 The above and other features and advantages of the present invention will be more
apparent from the following detailed description taken in conjunction with the
accompanying drawings, in which:

FIG. 1 is a frontal view showing a partial body view of a cooling apparatus
employed in a conventional drawing tower;

20 FIG. 2 is a constructional view of an optical-fiber drawing apparatus, which
employs a cooling apparatus in accordance with a preferred embodiment of the present
invention;

FIG. 3 is a side view showing the external appearance of a cooling apparatus used in high-speed drawing in accordance with a preferred embodiment of the present invention;

FIG. 4 is a side view showing a layout of turbulence generators in accordance with a preferred embodiment of the present invention;

5 FIG. 5 is a cross-sectional view taken along the line X-X;

FIG. 6 is a cross-sectional view taken along the line Y-Y; and,

FIG. 7 is a cross-sectional view showing the cooling apparatus shown in FIG. 4 in the disassembled state.

10 **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

Hereinafter, preferred embodiments of the present invention will be described in detail with reference to the accompanying drawings. For the purposes of clarity and simplicity, a detailed description of known functions and configurations incorporated
15 herein will be omitted as it may make the subject matter of the present invention unclear.

FIG. 2 is a schematic diagram showing optical-fiber drawing components mounted within a drawing tower. In particular, FIG. 2 shows two cooling apparatuses 10 for high-speed drawing employed in the optical-fiber drawing facilities according to the embodiment of the present invention. However, it should be noted that more than two
20 cooling apparatuses may be implemented according to the teachings of the present invention. Thus, the number of cooling apparatuses in FIG. 2 should not limit the scope of the invention.

As shown in FIG 2, the process for drawing an optical fiber is performed sequentially in the drawing tower (the height of which is at least 10 m) in the downward vertical direction. Initially, an optical-fiber preform P is provided and centered on the vertical axis of the drawing tower and melted within a melting furnace 8 to a sufficiently high temperature, then drawn to a single-strand optical fiber F1. The diameter of the drawn optical fiber F1 is controlled by a diameter controller 9 and passes through the cooling apparatus 10 of the present invention, so that the fiber can be cooled to an appropriate temperature for coating the cladding thereon. The cooled optical fiber F2 is coated with a cladding while passing through a coating device 16 and then ultraviolet (UV) curable polymer, which has been coated on the circumferential surface of the optical fiber, is cured while the optical fiber passes through a UV curing device 18.

Following this process, the optical fiber which has passed through the curing phase passes through a capstan 19 and a plurality of guide rollers 22 and 24 and then eventually wound on a winding unit 26. The capstan 19 provides a predetermined drawing force so that an optical fiber with a constant diameter can be drawn from the optical-fiber preform. Reference numeral 26a indicates a reel or a spool to which the optical fiber is finally wound.

Each of the optical-fiber drawing facilities mounted within the optical-fiber drawing tower is maintained with a vertical or horizontal relationship with each other and has a construction impervious to vibration or impact. In particular, the cooling apparatus 10 serves to evenly cool the drawn optical fiber F1. The vertical height of the drawing tower shown in the drawings exceeds about 10 m, and the optical fiber drawn from one optical-fiber preform P will have a vertical span exceeding about 10 m. The cooling

apparatus 10 performs the function of cooling the optical fiber F1 to about 40 °C as the optical fiber F1 is drawn at a high temperature and high speed.

Now, a detailed construction of the cooling apparatus in accordance with the present invention will be described with reference to FIGs. 3 to 7.

5 As shown in FIGs. 3 and 4, the cooling apparatus 10 is used in high-speed drawing (hereinafter referred to as “cooling apparatus”) of an optical fiber to cool an optical fiber to a desired temperature appropriate for coating the drawn optical fiber. It should be noted that at least one cooling apparatus can be mounted in the drawing tower. The cooling apparatus 10 is constructed so that it can be automatically opened, closed, and controlled. A means
10 for automatically opening, closing, and controlling the cooling apparatus is not shown nor discussed as they represent subject matter not covered by the present invention. The cooling apparatuses 10 are installed with a turbulence generator 140 within a cooling body 110, thereby minimizing the amount of cooling gas utilized as a refrigerant (He, Ar, N₂).

FIG. 3 is a side view showing an external appearance of the cooling apparatus
15 according to the present invention. In the drawing, an optical fiber which would be concealed by the cooling body is illustrated. FIG. 4 shows a state in which four turbulence generators are employed and mounted within the cooling apparatus in accordance with the present invention.

Referring to FIG. 3, the cooling apparatus 10 comprises a left-right separable
20 cooling body, which is composed of a left cooling body part 112 and a right cooling body part 114; upper and lower sealing caps 120 and 130 that are provided on the upper and lower ends of the cooling body 110, respectively, to block the ingress of external air,

wherein cooling gas is supplied into the cooling body through the sealing caps; at least one turbulence generator 140 positioned at a predetermined position in the longitudinal direction of the cooling body 110 to further activate the molecular movements of the cooling gas introduced into the cooling body 110.

- 5 The cooling body 110 is extended to a predetermined length in the longitudinal direction of the optical fiber F1 and allows the optical fiber, which is drawn along the longitudinal center line within the cooling body, to be cooled to an appropriate temperature. The upper and lower sealing caps 120 and 130 are provided to prohibit the ingress of external air produced during high-speed drawing, in particular by providing a counter-flow.
- 10 Note that the left cooling body part 112 and right cooling body part 114 are integrally assembled by adjoining them in the direction indicated by arrows ㊦ and disassembled by separating them in the direction indicated by arrows ㊧.

The turbulence generator 140 serves to cause the molecular flow of the cooling gas (i.e., helium gas), which is supplied to the interior of the integrally assembled cooling body

15 110, to be turbulenced, thereby maximizing the cooling efficiency. Each of the left side cooling part 112 and right side cooling part 114 is provided with one turbulence generator 140, and at least one turbulence generator is provided in the longitudinal direction of the cooling body 110. Note that the turbulence generators are mounted in the left side cooling part 112 and right side cooling part 114 in a symmetrical fashion. As the turbulence

20 generators 140 communicate with the atmosphere surrounding the external circumference of the drawn optical fiber F1, through slots S, the optical fiber F1 is directly influenced by the turbulent movements of the cooling gas caused by the turbulence generators.

As shown in FIGs. 5 to 7, the left and right cooling body parts 112 and 114 are supplied with cooling water W of low temperature without intermission and the cooling water continuously circulates from a predetermined position. The cooling water W absorbs heat from the cooling body 110 heated by the drawn optical fiber F1 and thus primarily
 5 cools the atmosphere surrounding the optical fiber F1.

In addition, the left and right cooling body parts 112 and 114 are provided with helium gas 146, which is supplied to cool the atmosphere surrounding the optical fiber F1. Both of the cooling water W and helium gas 146 are symmetrically stored and supplied in the left and right cooling body parts 112 and 114. The cooling water W is provided to
 10 circulate continuously in the longitudinal direction of the cooling body and the helium gas 146, and the cooling gas is provided in the circumferential direction of the drawn optical fiber F1 and directed toward the surface of the optical fiber.

The turbulence generators 140 are preferably comprised of cooling fans, and the slots S are provided so that the ventilation produced by the cooling fans 140 produces
 15 turbulence and communicated with the drawn optical fiber F1. The ventilation caused by the cooling fans 140 has direct influences on the optical fiber F1 and in turn maximizes the cooling efficiency. Although the drawn optical fiber runs at a high speed, the cooling efficiency of the helium gas can be maximized because the ventilated flow provided in the circumferential direction of the optical fiber F1 by the cooling fans 140 is mixed with the
 20 helium gas 146 and makes direct contact with the optical fiber F1.

In addition, at least one vibration-damping jig 142 is mounted in the longitudinal direction of the drawn optical fiber F1, especially between the cooling fans 140 and the

optical fiber F1 and thus maintains the evenness in the quality of cooling the optical fiber using the supplied cooling gas 146. The vibration-damping jig 142 consists of two members that have a predetermined curvature radius and faces each other symmetrically with reference to the drawn optical fiber F1.

5 Consequently, the cooling gas 146 turbulenced by the cooling fans 140 interfaces the high-temperature optical fiber being drawn at a high speed, while the turbulent cooling gas makes contact and its high molecular movement serves to actively cool the surface of the optical fiber.

 The operation of the cooling apparatus 10 constructed as described above will be
10 specifically described herein.

 At the time of drawing an optical fiber from the optical-fiber preform, which is positioned in the melting furnace and has undergone preheating and heating processes, if the drawing velocity of the optical fiber F1 (the linear velocity is about 200 ~ 500 meter per minute: mpm) increases to apply tension to the optical fiber F1, the left and right cooling
15 body parts 112 and 114 are joined together to form a single body -- i.e., the cooling body 110. At the same time, the upper and lower caps 120 and 130 are integrally engaged to the cooling body 140, and then the cooling gas 146 is supplied to the cooling body 110. Following this process, if the linear velocity of the basically tensioned and drawn optical fiber reaches to about 700 ~ 1000 mpm, the turbulence generators 140 are operated. The
20 turbulence generators 140 increasingly activate the molecular movements of the cooling gas 146 with their production of turbulence, and the cooling gas supplied through the slots S absorbs and transfers heat from the surface of the optical fiber F1 to the surface of the

cooling body 110. Note that the slots S are provided through the internal wall of the cooling body 110 and extend vertically to the drawn optical fiber F1.

Thereafter, if the optical fiber is severed or terminated, the cooling body parts will be automatically moved apart from each other, thus opening the cooling body and the
5 drawing process will be terminated without needing a separate flush step. Preferably, the quality of cooling the optical fiber by the cooling gas is maintained uniformly by the vibration-damping jigs 142 provided in the cooling body 110 along the longitudinal direction of the drawn optical fiber F1.

A drawing tower may be provided with at least one cooling apparatus according to
10 the present invention, and it is preferable to employ two cooling apparatuses 10, as shown in FIG. 2.

As appreciated from the above, the cooling apparatus according to the present invention allows high-speed drawing using a turbulence generator to enhance the productivity of an optical fiber. Furthermore, the present invention can reduce the amount
15 of cooling gas consumed by using turbulence generators, thereby increasing the competitiveness of costs.

While the invention has been shown and described with reference to certain preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and
20 scope of the invention as defined by the appended claims.